2 µm CASCADED RAMAN SCATTERING EMISSION FROM As_2S_3 HIGH-Q MICROSPHERES

Francis Vanier[1], Yves-Alain Peter[1], Martin Rochette[2]
[1]Polytechnique Montreal, Canada
[2]McGill University, Canada
E-mail: francis-2.vanier@polymtl.ca

ABSTRACT

This work presents first experimental measurements of cascaded stimulated Raman scattering emission from high-Q As_2S_3 microspheres in the mid-IR region of 2 µm. The pumping setup used is self-frequency locked on the microsphere resonances. Using a pump signal in the 1880 nm band of thulium, high order stimulated Raman emission up to the 3rd order and reaching a band centered at 2355 nm has been observed.

INTRODUCTION

The generation of mid-IR light in the wavelength range of 2-6 µm is crucial for molecular detection and spectroscopy applications. Stimulated Raman scattering (SRS) and cascaded SRS are important processes since SRS provides gain virtually for any wavelength inside the transparency range of the material. Chalcogenide glass such as As_2S_3 is a good candidate for mid-IR emission owing to a strong Raman gain and transparency up to a wavelength of 6 µm [1]. SRS and cascaded SRS emission were shown in As_2S_3 fibers at 3.34 µm and 3.77 µm [2,3] and in As_2Se_3 tapered fibers at a wavelength of 1.6 µm [4,5]. In addition to using chalcogenide glasses for their good optical properties, some waveguide geometries are preferred to others. For instance, whispering gallery mode (WGM) optical microcavities such as spheres or disks are excellent media for SRS emission owing to their high-Q resonances and small optical mode volumes. SRS emission and lasing in As_2S_3 was recently shown in high-Q spheres [6]. In this work, we report the first experimental measurements of cascaded SRS emission in As_2S_3 microspheres in the 2 µm spectral region. Third order Raman emission is observed from a pump wavelength of 1880 nm.

EXPERIMENTAL SETUP

To generate cascaded SRS emission inside the microcavity, we used a self-frequency locking laser scheme showed in Fig. 1 [7]. A 1550 nm pump signal is sent to a 32 cm Tm-doped silica fiber. An 1880 nm gain emission circulates in the fiber cavity in the direction imposed by the isolator. The gain emission is evanescently coupled to an As_2S_3 microsphere using a silica fiber tapered to a diameter of 2 µm.

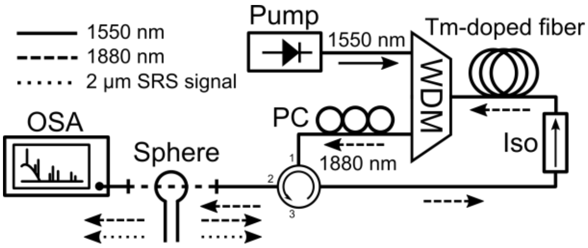

Figure 1. Setup of the Raman-based microsphere laser.

The microsphere has a diameter of 50 µm. The microcavity acts as a mirror for specific high-Q resonance wavelengths. When the gain inside the fiber loop reaches the threshold condition, laser lines in a wavelength band centered at 1880 nm are observed. In return, the 1880 nm signal pumps the cascaded SRS emission in the microsphere when SRS threshold conditions are achieved. The 1880 nm signal and the forward SRS emission are measured by a Yokogawa AQ6375 optical spectrum analyzer (OSA). The signal polarization in the fiber loop is optimized with a polarization controller (PC).

CASCADED STIMULATED RAMAN SCATTERING EMISSION

Fig. 2 shows a typical cascaded SRS emission spectrum. The multimode transmitted signal is visible in a band centered at 1880 nm for a 1550 nm pump power of approximately 875 mW. SRS emissions up to the 3rd Raman order are measured in bands

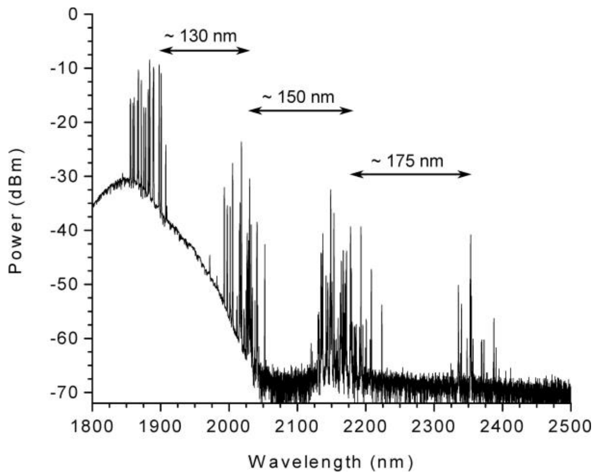

Figure 2. Cascaded SRS emission spectrum over the 2 µm mid-IR region. SRS emission up to the 3rd order is shown.

centered on 2030 nm, 2180 nm and 2355 nm. Measurements of higher Raman order emission beyond 2500 nm are limited by the OSA wavelength range. The Raman shifts of 130 nm, 150 nm and 175 nm correspond to the Raman frequency shift of 10.3 THz found in literature [1]. In this multimode regime, many pump modes can contribute to the gain of many SRS emission modes. Mode competition then causes fluctuation of the output Raman signal power especially with increasing pump power. A single pump peak results in a more stable output power of the Raman signal.

Fig. 3 shows the forward 1st and 2nd Raman signal power as a function of the transmitted 1875 nm pump power in a configuration where a single 1875 nm pump peak is present. The 1st and 2nd Raman order peak wavelengths are 2010 nm and 2170 nm respectively. The plain and dotted lines show the square root and linear dependency of the 1st and 2nd Raman order respectively [8]. For a transmitted pump power threshold of approximately 750 µW, the 1st Raman order peak saturates and the 2nd Raman order peak grows as expected. In saturation, the 1st Raman order output power diverges from the square root dependency and is clamped until a 3rd Raman peak appears [8]. Large power fluctuations due to modal competition on the 3rd order Raman laser emission prevent reporting a sufficiently reliable power evolution characterization.

The high purity As_2S_3 glass provided by CorActive High-Tech has an attenuation below 0.5 dB/m over the mid-IR range of 2-5 µm. Considering this attenuation value as the limiting losses source, an intrinsic Q factor above 2×10^7 is obtained across this range. Since a laser melting process already produced high-Q microspheres near this attenuation

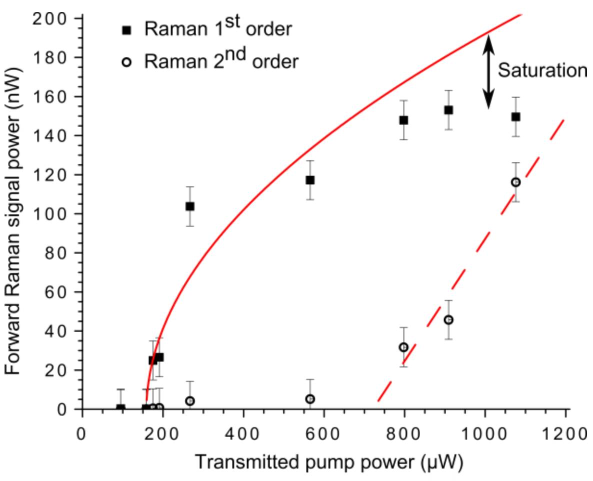

Figure 3. 1st and 2nd order forward Raman signal power threshold measurement.

limit in the telecom band [6], we expect similar behavior at 2 µm. SRS input threshold power at 2 µm is expected to be below 1 mW.

CONCLUSION

We reported the first measurements of cascaded SRS emission in high-Q As_2S_3 microcavity spanning over a band of 2030 nm up to 2355 nm. Based on a self-frequency locking laser setup, Raman scattering emissions up to the 3rd order were observed at a wavelength of 2355 nm with a pump signal centered at 1880 nm.

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